Refinement and Validation of the Sequence Model

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Award Number: N000140110017

LONG-TERM GOALS

A key goal of the STRATAFORM program has been to use observations of sedimentary processes operating on short time scales to improve our understanding of the development of stratigraphic sequences over time scales of 10^4 - 10^6 years. Tremendous progress in modeling sedimentary processes has been made under the program. However, further work is needed to achieve the goal of a process-based model for predicting the development of stratigraphic sequences. The Post-STRATAFORM modeling effort is focussed on two integrative, sequence-oriented modeling systems based on the SEDFLUX and SEQUENCE models.

The key development tasks for the SEQUENCE modeling system include a parameterization of slope and basin processes, linkage of the new slope and basin models into the model system, and model validation. My research contributes to the future development of SEQUENCE in three key areas: establishing rules for slope bypassing, specification of model forcing over long time scales, and testing of the SEQUENCE model against stratigraphic data in the STRATAFORM study areas.

APPROACH

Slope Bypassing. An inherent problem with a 2-D model like SEQUENCE is that it cannot directly account for shore-parallel transport of sediment. On continental slopes, sediment-gravity transport moves substantial amounts of sediment through submarine canyons and then redistributed on the continental rise. As a result, sediment supply to a 2-D section across the continental rise may be predominantly derived from the adjacent rise, rather than from the slope above. The new slope model used by SEQUENCE transports a user-specified proportion of the sediment leaving the shelf model directly to the lower slope and rise, bypassing the upper slope. This research focuses on examining the sediment distribution on real continental slopes rises and basins to determine reasonal numbers for that user-specified proportion.

A simple estimate of slope bypassing can be obtained by dividing the volume of sediment that has accumulated in the basin and rise by that which has accumulated on the entire margin. A gross estimate of long-term bypassing for a continental margin is thereby obtained from seismic sections with age control from nearby ocean drilling project sites for a variety of passive continental margins. This can be used to provide typical values for continental slope bypassing. Variations in these values can be assessed over space, by looking at results from a variety of margins, and over time, by comparing slope and basin sediment accumulation for the same margin over different periods of time. Long-term bypassing rates estimates would focus on passive margins, where structural deformation

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE
Refinement and Validation of the Sequence Model

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Physics and Geology, University of Texas - Pan American,,1201 W University Dr.,,Edinburg,,TX, 78539

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
key goal of the STRATAFORM program has been to use observations of sedimentary processes operating on short time scales to improve our understanding of the development of stratigraphic sequences over time scales of 104 - 106 years. Tremendous progress in modeling sedimentary processes has been made under the program. However, further work is needed to achieve the goal of a process-based model for predicting the development of stratigraphic sequences. The Post-STRATAFORM modeling effort is focussed on two integrative, sequence-oriented modeling systems based on the SEDFLUX and SEQUENCE models.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

does not interfere with the recognition of the ages of the sediments. The sediment budgets of active margins, however, would also be studied, but over shorter (e.g. late Pleistocene) time scales.

Long-Term Forcing. Many factors that can be regarded as constant over short time scales become variables in long term simulation. In order to pursue long-term simulations, we must address two important questions: 1) What was the climate like during the time being simulated?; and 2) How do changes in climate translate into SEQUENCE model parameters? The first question was addressed by an examination of regional pollen records, faunal data, and the predictions of Global Climatic Models for the New Jersey and Eel Margin sites. The impact of climatic change on sediment supply is modeled in the RIVER component of SEDFLUX. There are few direct ways of estimating past wind speeds and storm frequency, but some estimates can be obtained from climatic models. These estimates will be used to experiment with the diffusion coefficient when Alan Niedoroda and Chris Reed of Woodward-Clyde have constrained its relationship to hydrodynamic climate. The width and steepness of the shelf, which will vary in response to sea level, should also affect the diffusion coefficient.

Model Validation. Once there are constraints on the bypassing and forcing functions, I will work with Donald Swift and Steve Parsons of Old Dominion University on the model validation. There will be two stages of this work: an initial stage working with the single-grain size version of SEQUENCE (which is already available), and a final stage when the FACIES model has been integrated with the model. The Old Dominion University group is developing the facies model and will be instrumental in providing advice on input parameters for that model, as well as constraining data.

I will focus on the generation of the past 125,000 year sea level cycle in New Jersey and the northern California margin. The validation process will concentrate on determining whether simulated thicknesses,sedimentation rates, and acoustic properties predicted by the final model are similar to those observed, and whether all the major surfaces seen on the seismic records are created. Other issues are whether the implied mechanisms of surface formation are realistic, testing the sensitivity of the model to poorly constrained input parameters.

WORK COMPLETED

Shore-perpendicular seismic sections and age data from Ocean Drilling Project sites were compiled for the continental margins of Argentina, Gabon, Congo, southeast Greenland, eastern South Africa, California, Peru, Ghana, New Jersey, and northern Norway. Three passive margins--Argentina, Gabon, and Southeast Greenland--were chosen to represent margins with differing climatic conditions, sediment inputs, and slope angle. Southeast Greenland has an extremely steep slope angle and a dominantly glacial sediment input. Argentina has a moderate slope angle and climate and an extremely wide shelf. The Gabon example represents a comparatively gentle slope angle, with a very high riverine sediment input.

For each of these margins, representative seismic sections were chosen from published sources, and the sediments accumulating on the margin were divided into shelf, slope, and basin sediments based on geometric considerations. The proportion of continental margin accumulating on the slope was compared to that accumulating in the basin for the entire period represented on the sections, and also for time intervals between readily identifiable seismic horizons. Thus, long-term average slope bypassing, and slope bypassing for specific intervals for these four margins was obtained. Pleistocene

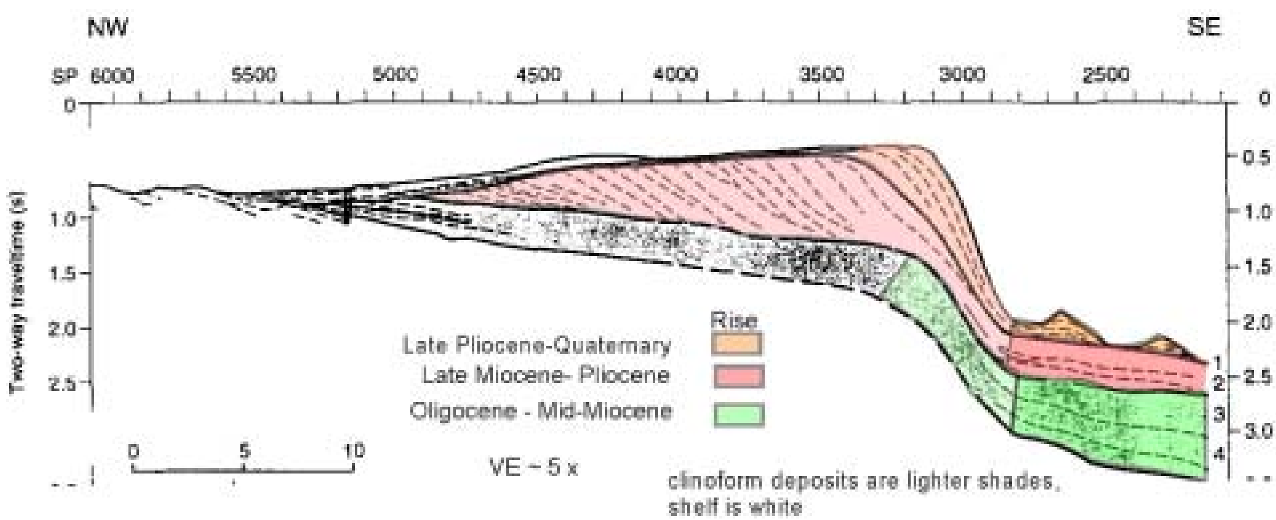
sedimentation rates from the Gorda Basin were compared to approximate sediment inputs in northern California to obtain an estimate of the proportion of slope bypassing for that margin.

The single-grain size version of SEQUENCE was installed in South Texas, and preliminary experiments were begun with the new slope and rise algorithm.

RESULTS

The most striking result of the Greenland margin is that a very high proportion of continental margin sediments accumulated in the Irminger Basin. For example, the shore normal section beginning along seismic profile 92-26, part of which is shown in Figure 1, implies that roughly nine times as much sediment accumulated on the 440 km wide abyssal plain at the base of the slope, as did in the prominent clinoforms. This pattern is at its most dramatic in the Oligocene-Middle Miocene section, where the slope deposits (light green in Fig. 1) are accompanied by a very thick (> 1 km) basinal package that extends without significant thinning for at least 60 km offshore into the basin. Even in the late Miocene-Pliocene and Quaternary sections, where the clinoforms are prominent, greater than 75% of the sediments were bypassed to the basin. Note that calculations were based on an assumpton of a seismic velocity of 1900 km/s in sediment.

The development of the clinoform, particularly in the middle-Miocene to Pliocene section (Fig. 1, shown in light pink) also bears noticing. Initially, a very gentle form that downlaps the sequence prominent middle-Miocene reflector, the clinoform becomes progressively steeper. This pattern is similar to that of other shelf clinoform packages, such as the middle Miocene clinoforms on the New Jersey margin (Steckler et al., 1999). The geometry of the seismic reflections appears to become more tangential for the steep clinoforms toward the shelf edge, suggestng that the sedimentation may have been minimal in deep water until the clinoform reached a certain slope.



`Figure 1. The Southeast Greenland Margin
[modified from Lykke-Andersen, 1998]

Initially, it was thought that the very large sediment accumulation in the Irminger basin might reflect extensive ice-rafted debris in this high-latitude region. However, the accumulation began prior to the onset of significant northern hemisphere glaciation.

Despite a different overall geometry and a very different setting, the margin of Argentina displays similar patterns in sediment budget. Sediment thicknesses on the continental slope since the Cretaceous, and within individual seismic units, are generally than those on the rise throughout the Argentine margin (from seismic data presented in Hinz et al., 1999). The basinal units continue without greatly diminished thickness for at least 150 km into the basin, indicating that approximately 85-90% of the sediment that reached the slope eventually passed onto the rise or abyssal plain.

Similar results were obtained for the Gabon-Congo continental margin, where there are thick accumulations of sediment in the Congo Fan and Angola Basin (Uenzelmann-Neben, 1998). Even with a conservative estimate of the sediment in the Angola Abysssal Plain, a value of approximately 85% was obtained for slope bypassing in this region. On none of the margins did the proportion of sediment sequestered in the slope or shelf clinoforms reach 25% for large stratigraphic intervals.

IMPACT/APPLICATIONS

The immediate impact is that it would appear that realistic values for slope bypassing are quite large; perhaps representing 80-90% of the total sediment reaching the shelf edge typically passes to the rise and basin. It is significant, however, that the seismic units described in these studies were all formed over long periods of time (3 million years or more). Examination of data with finer age resolution may reveal that substantial amounts of sediment are stored on the slope temporarily, then released to the basin during regrading phases. It should also be noted that only passive margins have been included in the study to date. However, STRATAFORM has collected evidence suggesting that a substantial proportion of the Eel River sediment load passes into deep water, even during high stands in sea level. The sedimentation rates reported for the Gorda Basin during the Pleistocene further support substantial sediment bypassing on the northern California margin throughout the Quaternary (Lyle et al., 2000).

In addition to providing a means of constraining slope bypassing in a numerical model, there are possible wider significances to the findings. Slope bypassing was found to be limited during steepening of the clinoform and very significant after the clinoform reached its maximum slope. This could imply a significant change in the sediment processes dominating margin sedimentation. One possibility is that sediment-gravity driven transport tends to be minimal until a threshold slope is reached, but afterward dominates the sedimentary regime, limiting further progradation.

RELATED PROJECTS

This work ties in closely with Michael Steckler of Lamont-Doherty, who has written most of the SEQUENCE model code, and has provided the framework for further development of the model. The slope and basin sediment budget work will help him to choose realistic slope bypassing values for the model. The sensitivity testing and model validation by comparison to stratigraphy will assist him in his model development, as modifications to the model will probably be suggested as the work progresses.

When the FACIES model is built into SEQUENCE, I will be working more closely with Donald Swift, Steven Parsons and others at Old Dominion Univeristy. They will be providing information on how

best to transform my climatic estimates into appropriate model parameters. They will also be working on characterization of the surficial and near-surficial sediments of the northern California margin, which will provide important ground truth for validating short term model runs of SEQUENCE. Alan Niedoroda and Christopher Reed of Woodward-Clyde will tie into this work by providing calibration of the model diffusion parameters to measurable hydrodynamic variables.

REFERENCES CITED

Hinz, K., Neben, S., Schreckenberger, B., Roeser, H.A., Block, M., Goncalvesde Souza, K., and Meyer, H., The Argentine continental margin north of 48°S: sedimentary successions, volcanic activity during breakup: Marine and Petroleum Geology, v.16, p. 1-25.

Lykke-Anderson, H., 1998, Neogene-Quaternary depositional history of the east Greenland shelf in the vicinity of Leg 152 shelf sites: Proceedings of the Ocean Drilling Program, Scientific Results, v. 152, p. 29-37.

Lyle, M., Koizumi, I., Richter, C., and Moore, T.C., Jr., Proceedings of the Ocean Drilling Program, Scientific Results, v. 167.

Steckler, M.S., Mountain, G.S., Miller,K.G., Christie-Blick, N., 1999, Reconstruction of Tertiary progradation and clinoform development on the New Jersey passive margin by 2-D backstripping: Marine Geology, v.154, p. 399-420.

Uenzelmann-Neben, G., Neogene sedimentation history of the Congo Fan: Marine and Petroleum Geology, v. 15, p. 635-650.

PUBLICATIONS

Parsons, S., Fan, S., Swift, D., Carey, J., Niedoroda, A., Reed, C., Storms, J., Crockett, J., Borgeld, J., Field, M., and Nittrouer, C., 2001, Largescale facies architecture on the Eel shelf: observations versus simulations: Chapman Conference on the formation of sedimentary strata on continental margins, Ponce, Puerto Rico. [abstract]